Tetra Tech EM Inc.

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February 3, 1998

Mr. Kevin Mayer
Associate Chief
Superfund Site Cleanup Branch
75 Hawthorne Street, SFD-7-2
San Francisco, CA 94105-3901

Subject: Potential Perchlorate Treatment Technology

Dear Mr. Mayer:

As discussed, I am forwarding to you information regarding an innovative treatment technology called capacitive deionization. The vendor for this technology, the Far West Group, believes that it may be an applicable perchlorate treatment technology.

If you should have any questions or are interested in receiving additional information, please feel free to contact me at 415/222-8201.

Sincerely,

Jill Yamada
Environmental Engineer

enclosures

A New Way To Concentrated Waste Water!!!

Introducing

Capacitive Deionization Using High Efficiency Electrodes

"Solid State Water Purification"

FAR WEST
Group, Inc. Tucson

WATER CONTAMINATION, A GLOBAL CONCERN

- Protecting the quality of our water resources is critical to sustain life into the future.
  - » Industry of past decades has contaminated the world's sub terrainian water deposits.
  - » Industry of today understands the problem and must remove contaminants before returning process water to the ground.
- The CDI process developed by Lawrence Livermore National Laboratory and Licensed by the FarWest Group is a water preservation tool.
  - » Contaminated ground water can be cleaned and returned.
  - » Industrial waste streams can be cleaned for recycling leaving highly concentrated effluent for efficient disposal.

THE AMMONIUM PERCHLORATE PROBLEM

- Early experiments at LLNL investigated the suitability of CDI for removing Ammonium Perchlorate from process water. In this instance generated during decommissioning of missiles.
  - Ammonium perchlorate (NH_4ClO_4) is a strongly oxidizing, corrosive salt used in the manufacture of solid rocket propellant.
- The CDI process separates the NH4 and ClO4 ions which are collected on negative and positive electrodes respectively.
  - Ions are discharged into a waste stream by grounding the electrodes.
    - » The waste stream can be used during many electrode discharge cycles to produce a highly concentrated effluent

TEST RESULTS

- 50ppm Ammonium perchlorate experiments by LLNL
  - » 5 litres at 2 ppm were produced using one pass over 39 square feet
- .15 litres of 41,000ppm chloride and sulfate process water experiments by Far West
  - » process water containing sulfuric acid, hydrochloric acid and sodium hydroxide at 41,000 ppm total dissolved solids was tested in our small demonstrator
  - » 3 passes over 4 square feet of aerogel reduced the total dissolved solids to 560ppm
    - electodes were cleaned between runs

SAMPLE EVALUATION

- The most effective method of determining the suitability of CDI to any application is by sample testing.
- For us to perform a "first glance" evaluation using the demonstrator we need
  - a water sample (1 litre)
  - an analysis of the sample
  - a listing of requirements for the "clean" water
- For detailed study of a problem we need
  - knowledge of water production rates
  - a study contract

University of California
Lawrence Livermore National Laboratory
Media Relations, Public Affairs Office

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FIRST COMMERCIAL LICENSE FOR HERALDED DESALINATION TECHNOLOGY

LIVERMORE, Calif. — Lawrence Livermore National Laboratory and Far West Group, Inc., a water resource management company with headquarters in Tucson, Arizona, have signed the first licensing agreement to commercialize a promising Laboratory desalination technology.

Capacitive deionization (CDI) created a flurry of interest when initial proof-of-principle test results were announced by the Laboratory two years ago. The key to CDI is the use of carbon aerogel, a material that has an enormous surface area. Solution is passed between closely spaced pairs of carbon aerogel electrodes. Ions such as sodium and chloride are removed from the flow and held in an electric field on the surface of the aerogel.

"We've been nurturing this technology for several years," said Jeff Richardson, of the Laboratory's Chemical and Materials Science Program Development Office. "We believe we've advanced it to the point where there is now an acceptable level of development for companies seeking to commercialize CDI. At the same time, finding the right first licensee was critical. We are confident the technology is in good hands at Far West Group, where enthusiastic and aggressive management is committed to making this a success."

"To borrow a term from the electronics industry, CDI is solid state water treatment," said Clark Vaught, CEO of Far West Group. "The challenge in front of us is to bring systems to market with a lower price tag than competing technologies."

CDI units as constructed by the Laboratory consist of rectangular stacks of pancake-thin titanium plates onto which the paper-thin aerogel is glued on both sides. The water to be purified snakes its way down through the stacks. When fully commercialized, these stacks may total in the tens of

thousands of electrodes, depending on the salinity and volume of the water to be purified. When the aerogel is "saturated" with contaminants, the voltage on the electrodes is reversed and the ions are dumped into a small waste stream.

One of the keys to commercialization of CDI is reducing the cost of manufacturing the aerogel. Although it is believed that mass production would lower such costs to less than $1 per square foot, it currently costs approximately $16 per square foot to produce carbon aerogel in test quantities.

Far West Group is addressing this challenge head-on by also licensing the production of carbon aerogel to ensure a steady and low cost supply for its internal use. The 14-year-old company, which became a public corporation in 1995, will simultaneously establish aerogel manufacturing capability and develop purification systems using aerogel from Laboratory stock. Such an approach would allow the company to quickly produce a demonstration unit for potential customers while also providing a test bed for engineers to gather performance data.

Providing simple water treatment to underdeveloped countries has been identified by Vaught as a key corporate interest. Consequently the first field demonstration of the technology by Far West Group is expected to take place in Uzbekistan later this year.

When the Laboratory first announced CDI in December 1994 it had less than 300 square feet of hand-made carbon aerogel on hand. The limited availability restricted the scope of testing, since a small stack of aerogel electrodes can only cleanse slightly brackish water before the aerogel is saturated. In the last two years, Livermore has increased its volume of aerogel to 4,000 square feet. This in turn has allowed the Laboratory to test water with concentrations of impurities on the order of 1,000-3,000 parts per million (the typical definition of "brackish" water).

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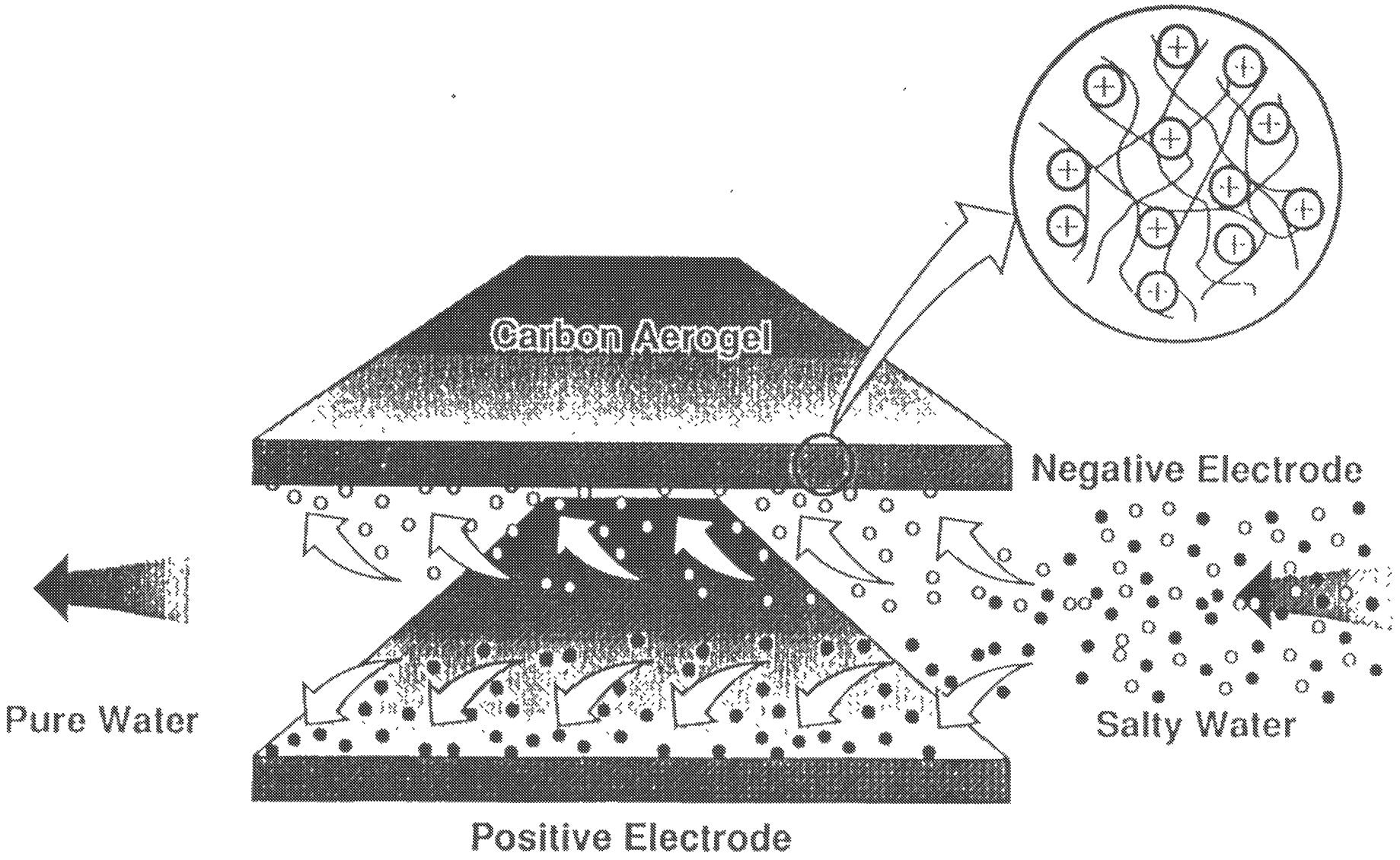


A single cube of carbon aerogel, one inch on a side, has an effective surface area of more than twenty million square inches. This unusually high effective surface area makes it possible to adsorb large numbers of ions.

UCRL-TB-110794-95

Carbon-Aerogel Capacitive Deionization of Water

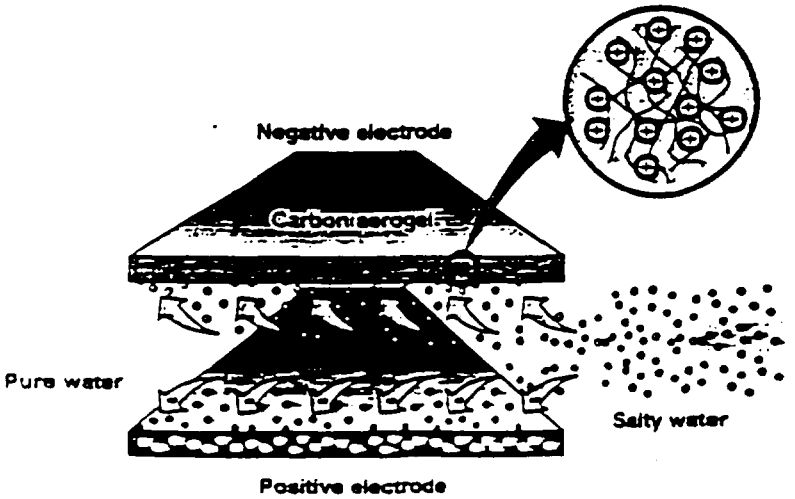
An efficient, economical process for purifying water

Capacitive deionization (CDI) with carbon-aerogel electrodes is an efficient and economical new process for removing salt and impurities from water. In the process, water is passed between electrodes kept at a potential difference of about one volt; nonreducible and nonoxidizable ions are removed from the water by the imposed electrostatic field and held at the electrode surfaces. When the electrodes become saturated with salt, they are electrostatically "regenerated," releasing the salts into a concentrated purge stream.

Carbon-aerogel electrodes have excellent stability in harsh chemical conditions and a very high specific surface area (600–1000 square meters per gram of aerogel), which enables the design of robust yet compact purifying systems. Carbon aerogels were developed at LLNL, and are now in commercial production. Their cost should drop considerably as their use in this and other applications increases. Some of the energy used in ion removal can be recovered during regeneration, improving overall energy efficiency.

APPLICATIONS

- Brackish water/seawater desalination
- Treatment of heat exchanger and boiler water, industrial and commercial process water and ultrapure industrial water
- Industrial waste water
- Municipal waste water
- Mixed hazardous and/or radioactive waste
- Mineral extraction
- Medical
- Domestic water softeners and refined drinking water treatment
- Analytical instrumentation



In the CDI process, salty water enters space between two carbon-aerogel electrodes; electrostatic field forces sodium and chlorine ions into aerogel, where they are held (inset); pure water leaves the space between the electrodes.

Advantages

The system has a simple, modular, plate-and-frame construction. It uses simple electrostatic regeneration, compared to ion-exchange systems that require acids, bases, or salt solutions for regeneration. CDI does not require the use of membranes or high-pressure pumps, which means the equipment is much more resistant to the effects of corrosive liquids (used to remove scale) than in other methods. And, CDI is more energy-efficient than competing technologies—far more efficient than thermal processes.

Our demonstration system has eight cells, containing 384 pairs of carbon-aerogel electrodes with a total surface area of more than two billion square centimeters (about 54 acres); yet the system occupies only a few cubic feet of space.

Energy efficiency. Brackish water (salt content of 800–3200 parts per million [ppm]) is conventionally purified using electrodialysis or reverse osmosis. Carbon-aerogel CDI uses 10–20 times less energy per gallon of purified water to achieve the same results. Purification of brackish water is an extremely important potential application of this technology.

For purifying seawater (32,000 ppm salt), carbon-aerogel CDI is just as energy-efficient as reverse osmosis, but without the need for costly and troublesome membranes.

Availability: The CDI patent was issued in 1995. The Laboratory is actively looking for industrial partners with whom to further develop and scaleup the technology.

Contact

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